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A METHOD FOR LOGGING THE PERFORMANCE OF A VEHICLE SUSPENSION SYSTEM

Field of the Invention.

The present invention relates to vehicle suspension systems
5 and in particular to a method for logging the performance of a vehicle
suspension system in reaction to impulsive loads applied thereto.

Background Art.

Methods for testing the performance of vehicle suspension
systems are generally known.

10 Automotive vehicles commonly employ a suspension system
connected between the road wheels and the body of the vehicle.

Conventional shock absorbers typically have a limited operating
life, and therefore may need to be replaced when they no longer function
properly. In order to determine if a shock absorber needs to be replaced, the
15 simplest and most widely used conventional diagnostic testing approach
typically involves a technician applying force to the vehicle fender, or
elsewhere on the vehicle body, and visually detecting the rocking movement
response of the vehicle. The resulting oscillations are often counted visually
or by an oscillation measuring device attached to the vehicle. The
20 conventional suspension testing approach therefore involves subjective
interpretation by the technician which may not be consistently reliable.

As can be appreciated, this test cannot feasibly be applied to
large vehicles such as road haulage trucks and the like.

Another test which may be applied is the European Drop Test, in
25 which a set of axles is mounted on a test rig and is driven over an inclined
ramp with a sheer drop of approximately 80 mm on its facing edge. The
damping ratio and frequency of the suspension is then measured using load
cells attached to the test rig.

The results gained in the above manners may be inaccurate and
30 inconclusive in that they do not accurately take into account the combined
effect of vehicle weight, suspension geometry and shock absorber
characteristics as they relate to the efficiency of the shock absorber in
maintaining the vehicle's wheel in contact with the road surface having regard

to the road bumps which the vehicle normally encounters.

Other known devices for testing shock absorbers test the dynamic reaction of suspension. These devices require the removal of the shock absorbers from the vehicle. This practice is highly impractical for two reasons. First, labour costs involved in the shock absorber's removal for testing and subsequent reinstallation are prohibitive, in that such costs may be equal to or greater than the cost of replacement shock absorbers. This is particularly true with shock absorbers founded in MacPherson-type suspensions wherein removal of the shock absorber necessitates the disassembly of other suspension components, such as the spring, balljoint and brake assembly.

Second, testing of a shock absorber isolated from its operating environment is believed to be unsatisfactory as its dampening ability is measured against an arbitrary standard rather than relative to the suspension system of which it is a part. As the performance of the shock absorber in conjunction with the rest of the suspension system affects the handling, ride, suspension performance, stability and safety of the vehicle, the practice of shock absorber testing as an isolated component can be seen to be unsatisfactory.

As the shock absorber must be removed from the vehicle in order to test the performance using this test, the vehicle must be removed from service for the length of the tests. This results in a loss of profits for the owner operator while the vehicle cannot be used during the period of downtime.

Other devices currently on the market, namely those operating on the seismograph principal evaluate the suspension systems as a whole, but are restricted to recording movement of the vehicle's body without allowing the deduction of the dampening factor of the system, (i.e., shock absorber performance).

With the advent of the Intelligent Access Project (IAP) under the NRTC guidelines and with the future introduction of Performance Based Standards (PBS), haulage or freight trucks may be called upon to comply with these standards which relate to the performance of suspension and

suspension components, as a whole or as a group of axles, so equipped. Under the IAP and the PBS guidelines, the vehicle suspension may be required to meet performance standards in order to maintain the compliance of the vehicle and its fitness for service. This compliance testing may test one
5 or more parameters of the suspension which determine the "road friendliness" of the suspension. A "road friendly suspension" may be one which functions within predetermined limits for one or more of the parameters, and attaining or complying with "road friendliness" may provide advantages for the owner/operator of the vehicle such as the ability to carry heavier loads or
10 access to roads which non-compliant vehicles may be restricted from using.

The compliance of the suspension is generally tested periodically over the life of the vehicle or the vehicle suspension.

It is therefore desirable to provide for an accurate test procedure for testing the performance of suspension components on a vehicle to
15 determine whether the suspension is functioning properly and within legally acceptable limits while the vehicle is in use and without requiring the removal of the vehicle from service. In addition, it is desirable to provide for a test procedure for testing vehicle suspension components that does not require subjective interpretation by a technician.

20 It will be clearly understood that, if a prior art publication is referred to herein, this reference does not constitute an admission that the publication forms part of the common general knowledge in the art in Australia or in any other country.

Summary of the Invention.

25 The present invention is directed to a method for logging the performance of a vehicle suspension system, which may at least partially overcome the abovementioned disadvantages or provide the consumer with a useful or commercial choice.

30 In one form the invention resides in a method for logging the performance of a vehicle suspension system comprising the steps of measuring the dynamic effect of an impulsive load with an electronic weighing system, wherein the electronic weighing system is mounted onboard the vehicle, and determining one or more parameters selected from the group

consisting of the dampening ratio of the suspension, the oscillation frequency of the suspension and the impact loading of the vehicle.

5 The method given above is preferably used to test the "road friendliness" of a suspension of vehicles. "Road friendliness" is assessed by the National Road Transport Commission (NRTC), and once a road friendly standard has been attained, the vehicle is allowed increased mass limits. The road friendliness of a suspension or suspension group, that is two or more axles connected together for load sharing as defined in the guidelines of the Higher Mass Limits (HML), is generally assessed under the current Higher
10 Mass Limits (HML), currently in force, according to two criteria, namely the damping ratio of the suspension and the frequency of oscillation of suspension in response to an impulsive load.

In order to be considered road friendly, suspensions must have a damping ratio of greater than 20 percent, meaning that the reduction in the
15 amplitude of oscillations which suspension undergoes in response to an impulsive load should decrease by greater than 20 percent each oscillation.

In addition to the required damping ratio in order to be considered road friendly, suspensions should have a frequency of oscillation of less than 2 Hz.

20 Preferably, components of an electronic weighing system mounted on board the vehicle may be used to measure and/or collect the data used according to the method of the present invention to calculate the damping ratio and frequency of oscillation. Typical electronic weighing systems may comprise at least one load cell or air pressure transducer,
25 associated with one or more suspension component. Each load cell or air pressure transducer may also be associated with a signal amplifier. Each signal amplifier may be associated with a central power module and a meter to display the data and/or the collated results of the tests performed.

According to a particularly preferred embodiment, the signal
30 amplifiers used according to the present invention may be "smart" amplifiers. These amplifiers may be capable of storing the results of calibration testing produced according to the invention. In this way, the calibration results are stored in each "smart" amplifier associated with each load cell or air pressure

transducer and are therefore not dependent on information storage in the meter.

The meter may preferably include a display, generally located in the cabin of the vehicle allowing review of the data or results by a driver. The
5 meter may also be associated with one or more remote display units and/or meters allowing review of the information gathered according to the method of the present invention, from a location remote from the meter located in the cabin of the vehicle.

Preferably, each suspension component may be provided with a
10 load cell or air pressure transducer. Accordingly, a central meter may be provided to which all load cells or air pressure transducers transmit the data. Such transmission may be along cabling or may be wireless transmission of data.

Suitably, the meter may be a multi-channel meter capable of
15 receiving information from up to eight channels. Preferably each of the channels may receive data from an axle grouping. Further, up to eight load cells or air pressure transducers may provide information to the meter on each channel. Therefore, a single meter may be capable of receiving and recording information from a total of up to at least 64 load cells or air pressure
20 transducers.

Each meter or system may preferably comprise an on-board storage device either built into the system or attached thereto such as a data log which suitably receives and records all information from all associated load cells or air pressure transducers. The data log may preferably allow the
25 tracking of the information collected according to dates, times, and particular dynamic parameters such as G-force and time both of which can be either pre-set or varied to suit particular operating conditions. Accordingly, all data collected may be provided with an identification code allowing the tracking of the data.

Typically, the meter from a single vehicle may be capable of
30 communication with a tool for analysis of the collected information, the analysis tool may be on-board either as a separate tool or built in to the system. In order to transmit and/or receive the information, the meter or

system in general, may be provided with a means for transmitting and/or receiving information. The means for transmitting and/or receiving information may preferably be in the form of a radio frequency data link, a telephonic link or any other type of the means for transmitting and receiving
5 information.

According to the present invention, each vehicle utilising the method of the present invention may be provided with a vehicle locating means. According to a particularly preferred embodiment, the vehicle locating means may preferably be a satellite global positioning system.
10 However, other locating means, such as trip meters, may be used according to the invention.

The method may utilise one or more remote interrogation units adapted to allow remote access to the meter provided in a vehicle. The remote interrogation units may allow the viewing and/or analysis of
15 information collected.

According to a first particularly preferred embodiment of the invention, the performance of the vehicle suspension system is logged over a standard road section at different times. This performance logging may be termed an "axle test". The purpose of the axle test may be to test the
20 performance of an individual axle or group of axles to an impulsive load and compare the results of the performance to the standards specified for road friendliness. The axle test may be performed when the suspension is new in order to establish compliance with the road friendliness criteria.

The axle test may be conducted at various periods throughout
25 the life of the suspension in order to ensure that the performance of the suspension remains within the accepted standards. The axle test may be conducted while the vehicle is in service and therefore may be termed "in service compliance" testing. Each of the parameters may be calculated from the data collected during the test.

30 The axle test may comprise a step test in which a specified height step downward is used to create a negative step input to the vehicle suspension for the purpose of determining damping ratio and fundamental frequency of axle-to-body bounce of the suspension. The step test may be

The trip test may be triggered by the application of a particular preset magnitude impulsive load. The test may further require that the location of the vehicle be ascertainable with precision. This may be accomplished using locating means such as GPS devices linked to the system. Upon triggering the trip test, the system may begin to record the performance of the suspension and the position of the vehicle when the test was triggered.

Suitably, the method of the present invention may be utilised to collect and analyse data in order to log the performance of the suspension of a vehicle. Individual components of the suspension may be tested or groups of components may be tested. The system allows the logging of information relating to the dynamic effect of impulsive loads applied to suspensions and the compliance of the suspension to parameters adapted to ascertain the effectiveness of the suspension in dampening the impulsive load applied.

Brief Description of the Drawings.

Various embodiments of the invention will be described with reference to the following drawings, in which:

Figure 1 is a schematic illustration of a typical installation of air suspension on an articulated vehicle such as a truck and trailer.

Figure 2 is a schematic illustration of a typical installation of a system according to an aspect of the present invention on an articulated vehicle such as a truck and trailer.

Figure 3 is a graphical representation of a test signal returned during a step test conducted using the system according to an aspect of the present invention.

Figure 4 is a graphical representation of a test signal returned during a bump test conducted using the system according to an aspect of the present invention.

Figure 5 is a graphical representation of the absolute value of the test signal returned during a bump test plotted against time conducted using the system according to an aspect of the present invention.

Figure 6 is a Fourier plot of a trailer axle group mass signal returned during testing conducted using the system according to an aspect of

conducted over a predetermined height step and also at a predetermined speed of passing over the step. The method may further allow the adaptation of the data to allow for differences in the speed and height of the step when calculating the tested parameters.

5 A second test which may suitably be used in axle testing is a bump test. This test may generally comprise a series of tests performed by driving a combination test rig vehicle over a 50mm bump at approximately 5km/h. The bump may extend upwardly or downwardly and may provide an approximation to a positive impulse signal applied to the suspension of the
10 combination test rig vehicle.

 A third test which may be performed may be a road test. According to this test, the variation in the mass signal may be recorded as the combination test rig vehicle travels along a normal, uneven road at speed. The speed may be up to 60km/h or may be higher if required. The GPS
15 location device may be linked to the data collected, to precisely locate the portion of road upon which the test was conducted for future comparison.

 Any one or more of the three tests described above may be conducted in order to assess the performance of the suspension.

 According to a second particularly preferred embodiment of the
20 invention, the performance of the vehicle suspension system is logged over a variable road section at different times, the position of the vehicle being identifiable at all times during the logging process.

 This testing procedure may be termed a "trip test". The trip test may preferably allow data to be collected about the condition of the roads
25 which a test vehicle travels over whilst gathering data in the form of the axle test for analysis, at the same time. Each trip test may be expanded into a series of axle tests for such purposes. For example, an impulsive load may be imposed on the suspension if the test vehicle drives over a pothole in the road. If a test vehicle uses the same route, it would generally traverse the
30 same pothole on different trips. By assessing the performance of the suspension in response to the impulsive load applied to the suspension on different trips, a user may determine whether the pothole is getting larger or deeper.

the present invention.

Detailed Description of the Invention.

According to an aspect of the invention, a method for logging the performance of a vehicle suspension system in reaction to impulsive loads applied thereto is provided.

Generally, trucks and trailers and other heavy haulage vehicles are equipped with self-levelling suspension systems. The systems are designed to compensate for changes in the load by modifying the springing characteristics of the suspension so that the trailer in particular, always remains approximately the same height off the road.

The systems are designed to ensure that, even when the vehicle is fully laden, the full upward travel of the suspension system is available for absorbing bumps. Other related effects are things such as the headlights are kept in proper focusing alignment, whatever the distribution of the load.

Any form of self-leveling is generally operated by one or more load-sensing devices which measure the vertical distance between, for example the trailer bed and the suspension arm. The greater the load, the smaller this distance tends to become. An initial variation in the distance operates a valve which controls the height-adjusting system. Usually, height adjustment takes place at both ends of vehicle, and in particular generally takes place at each axle.

Air suspensions are relatively simple in principle. Collapsible, pressurized air containers take the place of conventional springs or shock absorbers; the upward movement of the wheel reduces the volume of the air spring, raising its pressure, so that it tries to extend itself again. If the air spring is inflated more, it can carry a heavy load before contracting to a given height. A height-control valve connects the air spring to a high-pressure air reservoir when the load is increased, and pressure is released through the valve to the atmosphere when the load is reduced.

Air suspensions generally also comprise dampers, often incorrectly referred to as "shock absorbers". Dampers are designed to damp out vibrations so that the suspension does not continuously bounce up and down in response to an impulsive load. The purpose of dampers is to reduce

oscillation by absorption of energy stored in the suspension. A damper may be single action or double action in which damping is controlled in both directions.

5 A typical installation of the components of air suspension on an articulated vehicle such as a truck and trailer, which are also used according to the method of the present invention, is illustrated in Figure 1.

10 In order to control the air suspension system, the system has a meter 11 connected to a power supply 12 for the system usually including a battery 14. The meter 11 is also associated with a data transmitter/receiver 13 which is capable of transmitting data which is captured by the system to a remote location and receiving data and/or commands from a remote source. An example of a remote interrogation unit 15 is also illustrated in Figure 1. This unit is adapted for use to query the meter 11 onboard the truck when the truck is moving. Generally, radio frequency waves are used as a carrier
15 signal to accomplish the data transfer.

The system also has at least one and generally more than one smart amplifier 16 each associated with an air pressure transducer (APT) 17, or load cell or combinations of these, to acquire information regarding the gross and nett weights of the vehicle. Each air pressure transducer 17 is
20 associated with a component of the vehicle suspension. Generally, each APT 17 is associated with an axle or a shock absorber associated with an axle. Each APT 17 provides feedback to the meter 11 regarding the response of the suspension to an impulsive load by measuring the movement of the suspension.

25 As stated above, each axle is generally provided with an APT 17 so that the movement at each axle in response to an impulsive load may be monitored. The meter 11 and power module 12 are generally located in the truck or prime mover of the vehicle. These components are directly connected to the each APT 17 associated with the truck axles.

30 The APT's 17 and the associated smart amplifiers 16 which monitor the trailer axles are connected to the meter 11 and power module 12 on the truck using a quick release connector 18 so that different trailer may be connected to the one prime mover without loss of monitoring functions.

Providing the system with a handheld remote transceiver 19 allows the vehicle operator to remain safe distance from the vehicle while the vehicle is being loaded and still monitor the weights displayed on the remote receiver 19. Examples of information which may be collected include gross weight, nett weight, load delivery, front end weight, rear end weight, weight distribution, and mass management and suspension compliance testing.

The schematic layout of the components of the suspension system and electronic weighing system which is used to implement the method according to the present invention is illustrated in Figure 2.

10 The truck 21 and trailer 22 are shown with smart amplifiers 16 in place. Each smart amplifier 16 is associated with the in-cab hardware which allows a driver to monitor the performance of the suspension system of the truck and trailer combination which they are driving.

15 The smart amplifiers 16 are connected to a data logger 23. The data logger 23 is responsible for capturing and collating all of the information transmitted from the smart amplifiers 16 and the associated APT's.

20 The data logger 23 is in turn associated with a computer 24 which is responsible for the use of the raw information collected to create useable information regarding the parameters of the suspension which are to be monitored or tested. The system is also provided with a means to transmit and/or receive data or commands to and from a remote location 25, together with a locating means such as a GPS locator 26. The analysis of the information collected may take place at a remote location and the results transmitted back to the vehicle.

25 In use, the system collects weight information from air pressure transducers 17 connected to air bag suspensions, and/or load cells mounted on the vehicle. The information is then sent to the meter 11 where it is displayed in kilograms of weight applied at each individual axle or group of axles, as well as total weights. This allows the operator to check the weights on each axle group being used, as well as the axle group combinations and total weights as required on a display associated with the meter 11.

30 All information is date and time stamped and can be downloaded to a laptop 24 or a printer 27 in order to produce a hard copy on

demand. All data is stored in an associated data log 23 which cannot be deleted without a specific set of instructions (and password) from the operator.

5 The applicants have subjected the system and method to testing and analysis of the air suspension of a newly constructed, 34 tonne, four-axle trailer. The analysis is compared with the European Union (EU) requirements for "road-friendly suspensions" on heavy vehicles. Feasibility of determining road-friendliness of air suspensions for heavy vehicles without recourse to laboratory or workshop facilities was also explored.

10 **The Truck & Trailer Test Rig**

The truck was a standard Kenworth® prime mover with air suspension on the drive axles coupled to a 4-axle trailer with air suspension. This is an innovative vehicle which meets all but one of the 20 Performance Based Standards (PBS) as proposed currently by the National Road
15 Transport Commission (NRTC) specifications.

The trailer was built by O'Phee Trailers and the combination is owned and operated by a commercial carrying service. The truck/trailer combination has been on the road since mid February 2003 operating under permit. One of the conditions of the permit was that the vehicle was to be
20 monitored for mass and position. The Gross Combination Masses (GCM) permitted is dependant on the position of the combination test rig. The freight task is general freight/general access when the GCM is not to exceed 42.5 tonne and the GCM is not to exceed 50 tonne on a particular route between Acacia ridge and Lytton in Brisbane.

25 The combination rig was tracked using Global Positioning System (GPS) position fixes from a C-Trak GPS reporting system relayed back to a base station at the premises of Digicore, a third party service provider. The C-Trak system reports every hour via mobile phone link. The report contains the position of the vehicle in 6 minute intervals for the
30 preceding hour. The prime mover was equipped, before this trial, with the C-Trak GPS reporting system for fleet management purposes.

Mass data from the drive axles of the prime mover and the trailer group is measured indirectly, but proportional to, air pressure in the

high pressure air lines to the air suspension. Air pressure is converted to a mass signal by a mass measurement system which sends the mass signals to the C-Trak system as well as displaying the mass of the prime mover and the trailer on a display in the cabin. For the trailer, 40kg increments have
5 been assigned to the digital mass measurement by the mass measurement system. The mass on the prime-mover is determined by the mass measurement system apportioning a mass value to the steer axle and adding this to the measured value of air pressure on the drive group axle air line, proportional to the mass on that group.

10 It is cheaper to instrument air suspension than steel suspensions. To contain capital outlay, only the drive & trailer axle groups were instrumented and so the steer axle was not instrumented to measure mass. However, the geometry of the combination ensured a fairly constant mass on the steer axle. The trailer has a York® control system which raises
15 the front axle when the trailer is empty and drops the axle when a load is on board.

For the purpose of the testing, a container with freight weighing approximately 11 tonne was loaded onto the trailer.

The Tests Applied

20 The step test

The yard of the freight operator presented an ideal opportunity to replicate the EU step test. The EU test uses an 80mm step down to create a negative step input to the vehicle suspension¹ for purposes of determining damping ratio and fundamental frequency of axle-to-/body bounce.

25 A new warehouse was being built in the yard of the freight operator and the slab was finished, awaiting the superstructure. This slab was 65mm above the surrounding surface of the yard manoeuvring apron. For one series of tests, the combination test rig was driven off the warehouse slab onto the apron at approximately 5km/h.

30 The bump test

A second series of tests was performed by driving the

combination test rig over a 50mm water pipe at approximately 5km/h. The pipe had a bar welded to either end to prevent rotation as the tyres moved over it. The water pipe provided an approximation to a positive impulse signal applied to the suspension of the combination.

5 ***The on-road test***

A final test was performed by driving the combination test rig over some roads near the freight depot. The variation in the mass signal was recorded as the combination test rig travelled along normal, uneven roads at speeds up to 60km/h.

10 **THE RESULTS**

The step test

The step test results plotted in Figure 3 show that the signal is varying slowly and gives a shape that could not be analysed meaningfully. Figure 3 shows the test signal as measured for the first 2 axles, the first axle signal on the left 40 and the entirety of the signal on the right (from 2.25 s to beyond 4.92s) is from the second axle. The other 2 axles produced a similar shape to axle 1 and have not been included for brevity.

The bump test

The bump test yielded data that lent itself to more meaningful analysis and this data is shown in Figure 4. The three signals caused by the tyres from the 2nd, 3rd and 4th axles travelling over the pipe are shown in the Figure from left to right (41, 42, 43) respectively.

The second axle created the first excursion on the left of the graph. The signal generated by the first axle perturbation is not plotted here as it was similar to the two caused by axles 3 and 4, shown as the other two positive excursions in Figure 4.

The on-road test

The variation in the mass signal from the trailer axle group was of primary interest for this evaluation. A sample of how the data appears in hexadecimal format, this example from the on-road test appears below.

¹ Swatman, McFarlane, Ackerman, George. (1994)

89 88 87 86 84 83 81 00 02 04 07 09 0C 0E 2A 02 05 07 09 0B 0C 0D 0D 0D
 0D 0D 0D 0D 0D 0C 0B 09 07 05 03 01 00 82 84 86 89 8B 8D 8F 88 81 83
 85 86 87 89 89 8A 8B 8B 8B 8B 8B 8B 8B 8B 8A 89 87 86 84 82 00
 5 02 04 07 0A 0D 23 02 05 08 0A 0C 0D 0D 0E 0D 0D 0D 0D 0D 0D 0C 0C
 0A 08 06 04 02 00 82 85 87 8A 8C 8E 80 82 84 85 87 89 8A 8B 8B 8C 8C
 8C 8C 8C 8C 8C 8B 8A 89 88 87 85 83 81 00 03 05 08 0B 0E 27 02 05 07 09
 0A 0A 0A 0A 0A 0A 0A 09 09 09 07 06 04 02 00 81 83 86 88 8B 8D 8F F4 82
 84 85 87 89 89 8A 8A 8B 8B 8B 8B 8B 8B 8A 89 88 87 86 84 83 81 00 02
 10 05 08 0A 0D 0F 26 02 03 05 06 07 07 07 07 07 07 07 06 05 04 02 00 81
 84 86 88 8A 8D 8F 84 81 83 85 86 88 89 8B 8C 8C 8D 8D 8D 8D 8D 8D 8D
 8D 8D 8C 8B 89 88 86 84 82 00 01 04 06 09 0B 0E 24 02 04 06 07 09 09 09
 09 09 09 09 08 08 06 05 03 00 81 83 86 88 8B 8D 8F F6 82 83 85 86 88
 89 8A 8B 8B 8B 8B 8B 8B 8B 8B 8B 8A 88 87 85 84 82 00 01 04 06 09
 15 0C 0E 1D 02 04 05 06 07 07 07 07 07 07 07 07 06 05 04 03 01 00 81 83
 85 87 89 8B 8D 8F F3 81 83 85 86 87 89 89 8A 8A 8A 8A 8A 8A 8A 8A
 89 88 86 85 83 82 00 02 04 06 09 0B 0E 0E 02 04 05 07 08 08 09 09 08 08
 08 08 07 06 04 02 00 81 84 86 89 8B 8D 8F E0 81 83 85 86 87 88 89 89 89
 89 89 89 89 89 89 88 87 86 85 83 82 00 01 03 05 08 0A 0D F4 02 04 06 08
 20 09 0A 0B 0B 0A 0A 0A 0A 0A 09 07 05 03 01 81 83 85 88 8A 8C 8E E4 81
 83 84 85 85 86 86 86 86 86 86 86 86 85 85 84 83 82 81 00 01 02 04 05
 07 09 0B 0D 0F 16 02 04 05 07 08 09 09 09 09 08 08 08 07 06 04 03 01 81
 83 85 87 8A 8C 8E 85 81 83 84 85 86 87 88 88 88 88 88 88 88 88 88 88
 87 86 85 84 82 81 00 01 03 05 07 09 0C 0E 0F 35 01 02 03 04 04 04 04
 25 04 04 03 03 02 00 00 82 84 86 88 8A 8C 8E 8F 8B 81 83 84 85 87 88 88 89
 89 89 89 89 89 89 89 89 88 88 87 86 85 83 82 00 00 02 04 06 08 0A 0C
 0E 1C 01 03 04 04 05 05 05 04 05 05 04 04 03 02 00 81 83 85 87 89 8B 8D
 8F F7 81 83 84 85 87 88 89 8A 8A 8A 8A 8B 8B 8B 8B 0F B8

30 The data from the tests was converted and a plot of the variation
 in mass induced by the dynamic forces on the combination was produced as
 Figure 6.

Analysis

The step test

35 The step test did not yield any data that could be analysed in a
 meaningful way. It is noted that the EU test differs from the step test
 conducted in that it is conducted at much higher speeds than those used for
 this testing, it is done for one axle only and the drop is 80mm, not 65mm as
 used for this testing. The applicants surmise that the effect of the air lines
 40 equalising the pressure differential between the air bags on differing axles
 caused the signal to behave in the manner shown in Figure 3, particularly for
 axle 2. It was thought that the 3 axles were restraining the first axle in the

vertical plane as it went over the step but when the second axle encountered the step the applicants thought that that was the point of equilibrium of the axle group and the group then teetered like a see-saw, giving the resultant aberrant signal. The applicants also surmise that this was why the EU test
 5 was performed with only one axle and at higher speeds.

The bump test

By taking the absolute values² of the data from the first perturbation in Figure 4, that is, the first and third excursions of the mass signal, the damping ratio (ζ) may be determined³ using the formula:

10

$$\zeta = \delta / \sqrt{(\delta^2 + (2\pi)^2)}$$

where δ is the standard logarithmic decrement⁴ given by the following:

$$\delta = \ln\left(\frac{A_1}{A_2}\right)$$

15 and

A_1 = amplitude of the first peak 44 in the plot of the absolute value of the response and

A_2 = amplitude of the third⁵ peak 45 in the plot of the absolute value of the response.

20

From Figure 5, it can be seen that the value of $A_1 = 6$ and $A_2 = 1$. It is noted that these values are the closest approximation to the actual values measured by the mass measurement system given the approximately 1000 digitisation steps over the measurement range of 40T: (40000kg/1000 = 40kg increments).

25

Substituting the measured values of A_1 and A_2 yields a damping ratio (ζ) of 0.27 or 27%, allowing for the error described above.

The EU Standard is 20% or greater so it can be seen that this trailer meets the EU Standard for "road-friendly suspension" dampers. Further, this exercise shows that, by using a simple test of driving over a

² Milliken, De Pont, Meuller and Latto, 2001

³ Prem, Ramsay, McLean, Pearson, Woodrooffe and de Pont, 2001.

⁴ Meriam and Kraige, 1993

⁵ Milliken, etc, op cit

50mm pipe and analysing the data provided by the on-board mass measurement system, the damping ratio may be determined by simple calculation.

The on-road test

5 By subjecting the data from the on road test to Fourier analysis, the system is able to determine the trailer's body-to-axle-group frequencies induced by the dynamic forces on the combination. For this analysis, it was assumed that the signal derived from driving the vehicle on normal roads approximated to a random signal. Fourier analysis of an output, or derived,
10 signal after it has been generated from a random input signal of uniform amplitude to any system allows determination of the transfer function of the system as expressed by the frequencies present in the output signal⁶.

The plot illustrated in Figure 6 is a Fast Fourier Transform (FFT) that is, by definition, lumpy and does not yield pure and clean plots on the
15 magnitude axis. Even allowing for the overall noise created by the FFT process, it can be seen that the greatest frequency magnitude 46 present in the FFT of the on-road signal is that of 1.5 Hz – 2 Hz. Given that the EU standard for body bounce is > 2.0 Hz, it is statistically probable that this parameter is met by the suspension tested and reflected on this plot. It is to
20 be noted that some lower frequencies appear to be present and that there are greater magnitude frequencies at approx. 4 Hz, 8 Hz and 15 Hz. Axle hop⁷ appears to be the explanation for the 15Hz signal. Further research is needed for the 4 & 8 Hz signals.

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⁶ Chesmond, C.J, 1982

⁷ Conversation with Dr. Hans Prem.

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10

In the present specification and claims, the word "comprising" and its derivatives including "comprises" and "comprise" include each of the stated integers but does not exclude the inclusion of one or more further integers.

15

Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, the appearance of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment.

20

Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more combinations.

25

In compliance with the statute, the invention has been described in language more or less specific to structural or methodical features. It is to be understood that the invention is not limited to specific features shown or described since the means herein described comprises preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted by those skilled in the art.

Figure 1

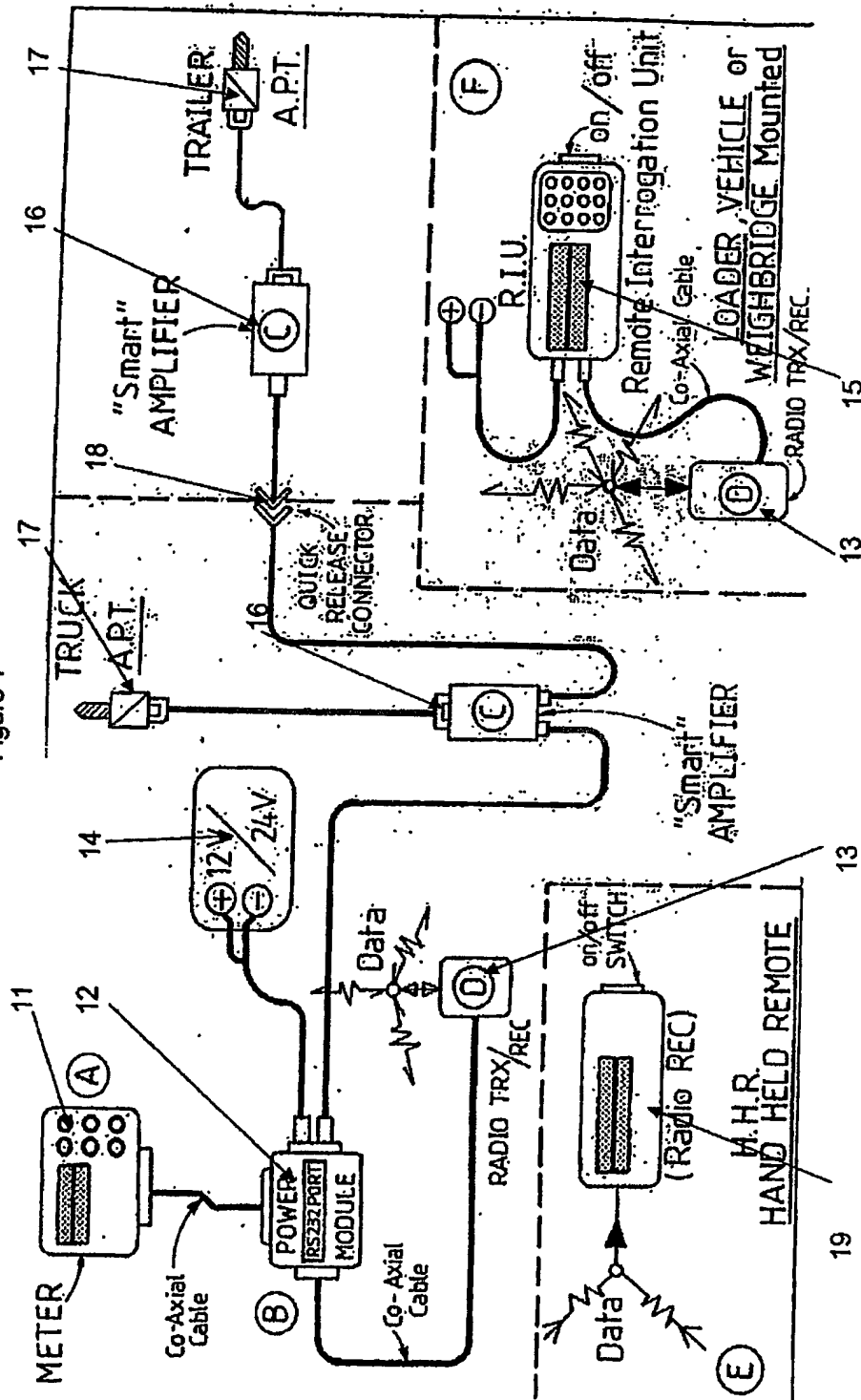
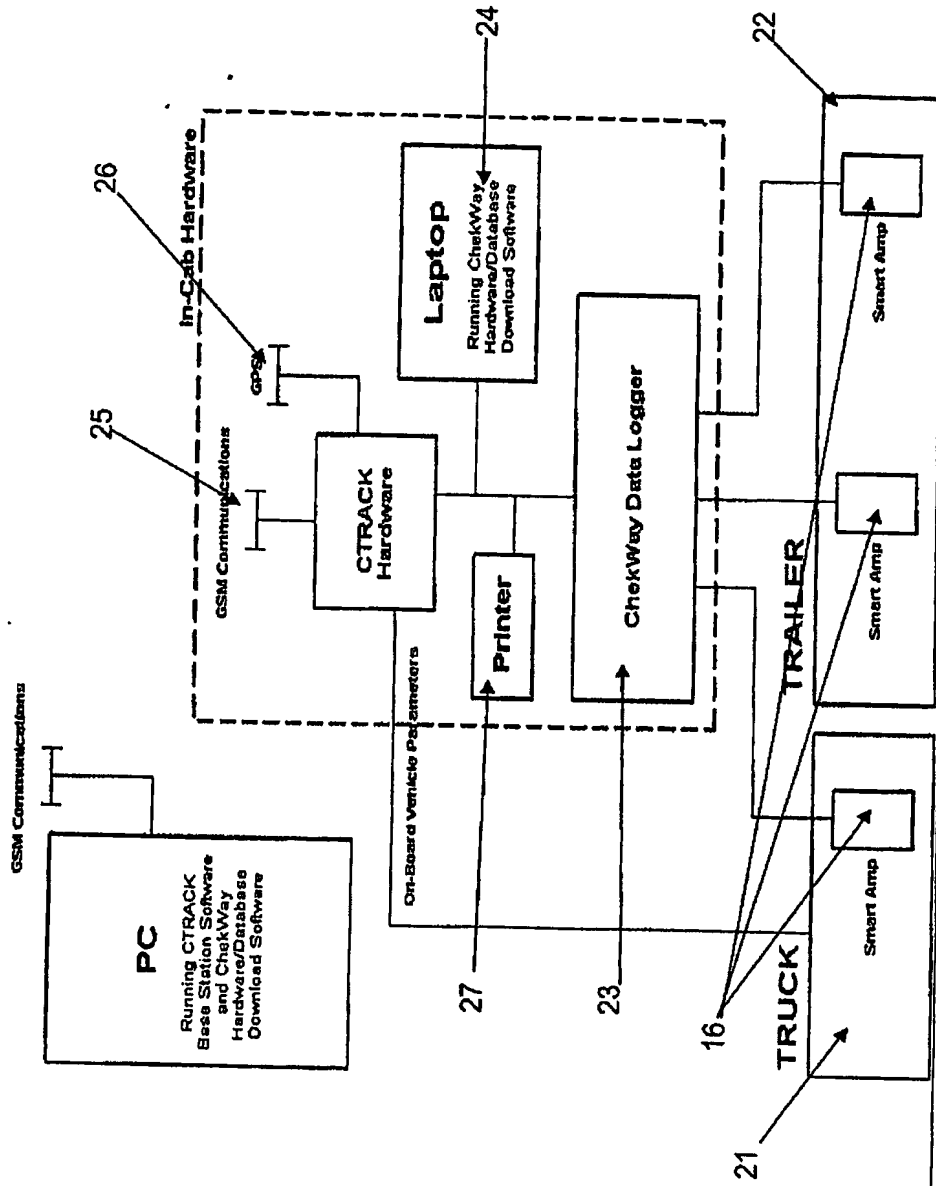


Figure 2



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Figure 3

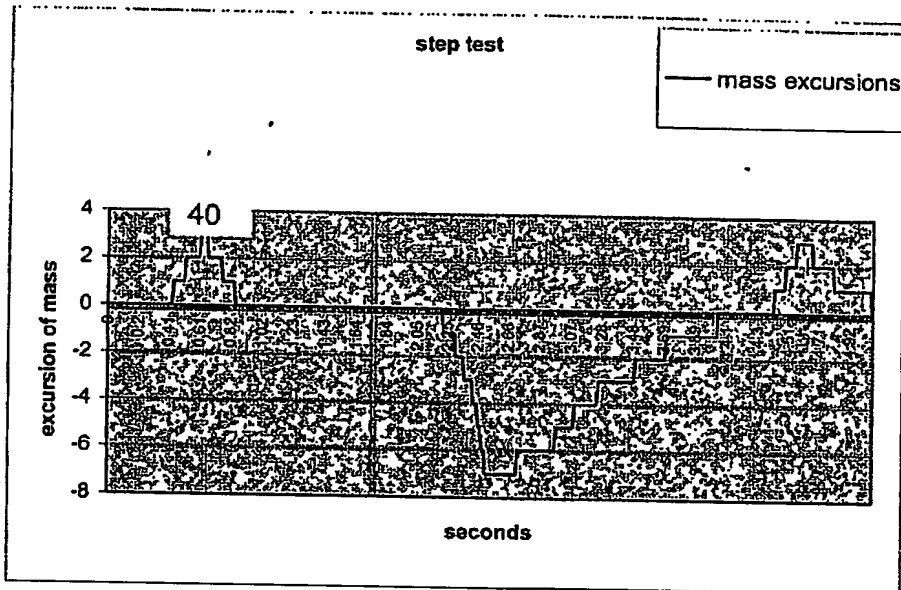
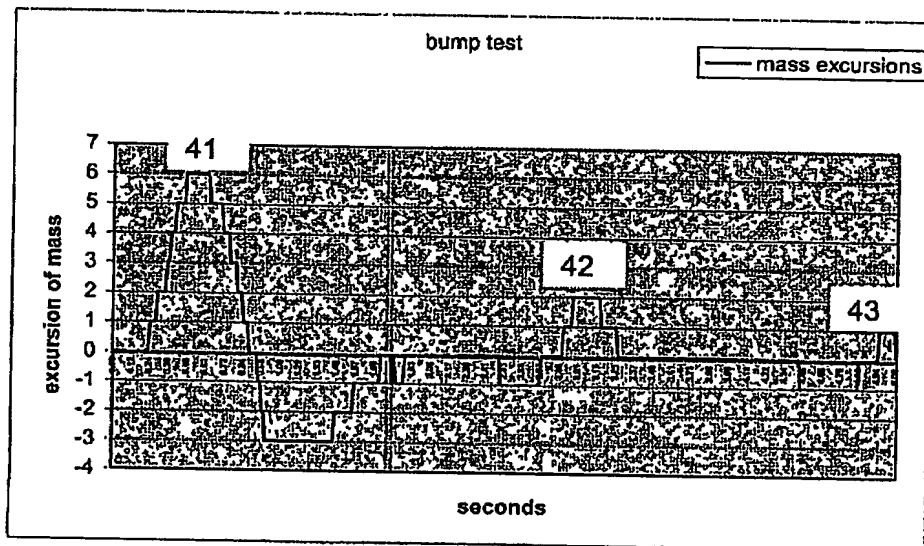


Figure 4



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Figure 5

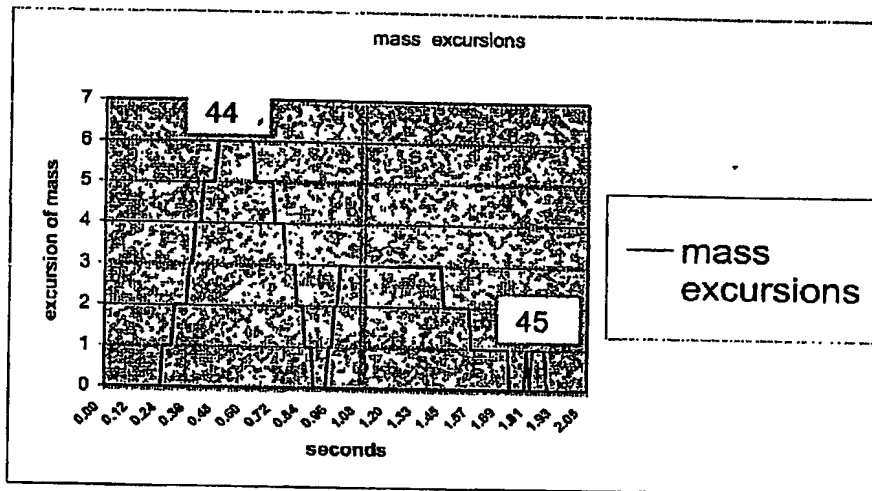
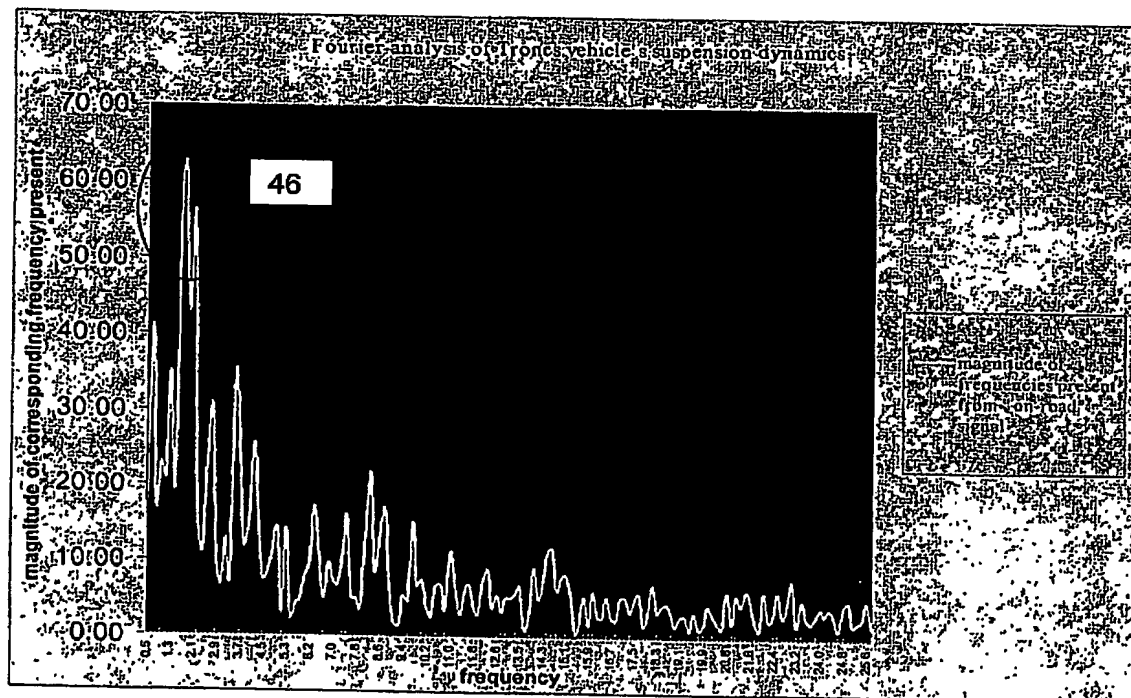


Figure 6



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